



Crop Drying, Preservation, and Storage

"Experience has taught the small grower in the developing countries that, if produce is stored, it goes bad. This has two effects: a sufficient quantity is grown to feed the family for about three or four months; immediately after harvest (sometimes before it has been dried thoroughly), when there may be a temporary glut of food and prices are low, produce is sold to traders; moreover, in many areas the farmers are in debt to the traders and any produce surplus beyond their own food requirements is immediately sold to meet accumulated debts. Thus one of the major contributory factors responsible for the economic nonviability of farming areas is the farmer's inability to handle and store food efficiently so that he can sell good quality produce when it is scarce and commands a high price. The standard of living in a rural community depends not only upon the range of foods grown, the capacity to grow in quantity, but also upon the facilities for efficient handling, drying, storage and marketing

"In Latin America it has been estimated that there is a loss of 25 to 50 percent of harvested cereals and pulses; in certain African countries about 30 percent of the total subsistence agricultural production is lost annually, and in areas of Southeast Asia some crops suffer losses of up to 50 percent."

—**Handling and Storage of Food Grains in Tropical and Subtropical Areas,**
FAO.

Many observers view effective farm level grain storage as an opportunity to reduce food losses and increase farm family income and security at the same time. Landless laborers may also benefit from good storage, as grain prices flatten out and in-kind wages can be protected from losses in their homes. Centralized government grain storage facilities frequently have proven to be a disappointment, suffering from poor quality control on incoming grain (with resulting high in-storage loss rates) that leads to low prices paid to the farmers. Even with smoothly functioning large-scale grain storage facilities substantial losses may have already taken place at the farm level before the grain ever reaches the centers.

Several studies of farm level grain storage losses in recent years have concluded that losses in the areas studied were much lower than previously supposed. Studies of this sort have some difficult methodological challenges to overcome, and the complete picture is not yet clear. Certainly there are farmers in some places with particular crops that are experiencing very low storage losses, while some farmers in other places are having high losses with other crops. People interested in this topic should carefully investigate the extent of local losses before launching programs.

Readers who are in a position to help develop or implement appropriate technology solutions in their communities should turn first to two excellent books that detail for different crops the points in the harvest, handling, and storage sequence where losses are most likely to occur. **Post Harvest Food Losses in Developing Countries** takes a look at the potential for reducing losses of a wide variety of foods, while **Handling and Storage of Foodgrains in Tropical and Subtropical Areas** is the better technical reference book, concentrating on grain storage. Another valuable source of ideas on how to approach storage problems is **Appropriate Technology for Grain Storage**, which describes a successful effort to pool community knowledge of grain storage problems and apply it to develop several solutions tailored to local circumstances.

Proper drying is considered the biggest single factor in determining whether grain will be effectively stored without damage. Simple direct solar drying already plays a major role in preserving a large portion of production in the South. Usually grain is dried while it stands in the fields, or it is spread out on concrete surfaces, roads, baskets, plastic sheets, or the ground itself.

The standard alternative to such methods has been the fuel-burning artificial dryer. In these units, large quantities of grain can be dried with greater speed and greater control over drying rate and product quality. These dryers require a high capital investment and ever increasing operating expenditures for fuel, but have relatively low labor costs. There are also a number of small artificial dryers that depend on wood, rice straw, or rice hulls for fuel (see **Drying Equipment for Cereal Grains and Other Agricultural Produce, Simple Grain Dryer, and Small Farm Grain Storage**).

Solar agricultural dryers have received much attention in recent years. (See **A Survey of Solar Agricultural Dryers** for a collection of different designs.) They are cheaper to operate than fossil-fueled dryers, requiring no fuel, and they are more easily made with low-cost local materials. There are two general varieties of solar dryers. The simplest (for certain crops such as corn) are raised bins with roofs, that protect the grain from rain and attack by small animals and rodents. They allow air to flow through wire mesh or woven walls to slowly dry the grain. These are "indirect" dryers that depend on air heated by the sun rather than direct exposure to the sun. They are widely used, low-cost, and effective for corn (maize). Much work

has been done recently on different dryers that are enclosed with glass or plastic coverings to trap the sun's heat, raising the temperature and lowering the humidity of the air which passes over the crops. Such dryers have a higher cost per unit of drying surface area than the other simpler systems. They offer some protection from dirt, insects, animals and rain (an advantage over ground-spread systems in which the grain must be quickly gathered up whenever rain threatens). For grain drying, however, enclosed solar dryers have a very small capacity compared to what is usually needed, and cost much more than a basic flat surface.

For fruits and vegetables, the temperatures achieved in an enclosed solar dryer make thorough drying possible when open air drying may not be rapid enough. Drying could extend the low-cost availability of a number of tropical fruits such as mangoes. In many countries these fruits ripen during a very short period, creating a temporary glut.

The appeal of solar dryers in the South will depend very much on the local situation—traditional drying practices, crops produced, food price fluctuations over the year, and weather during the harvest season. (No solar drying system works well under continuously cloudy, humid conditions. When harvests coincide with the beginning of a rainy season, a fueled dryer may be necessary.) In many areas, flat drying surfaces may be better investments than solar dryers. On the other hand, dryers made of local materials (e.g. bamboo, wood, adobe) and clear plastic sheeting or low-cost glass need not be very expensive.

In the United States, solar grain drying systems at the farm level are under active testing, and the results to date suggest that they will soon be widely used. These dryers are replacing expensive fossil-fuel burning dryers, and the costs of converting to solar drying can be balanced against reduced fuel bills. Most of these U.S. solar drying systems use large electric fans to circulate air. Two of the publications in this chapter describe these systems.

There are many good quality storage bins that can be made out of locally available, low-cost materials, that will successfully protect properly dried stored grain from moisture, mold, insects, rodents and birds. One such bin is the *bissa*, which appears to be well suited to storage requirements in Sri Lanka (see **Evaluation of the Bissa**). Lightweight metal bins have proven effective in Guatemala, India, and other countries (see **Guide to the Manufacture of Metal Bins**). Other traditional and low-cost storage bins are described in **Post Harvest Food Losses and Handling and Storage of Food Grains**.

In certain climates, some fruits and vegetables can be stored in underground structures and pits. Canning, drying and pickling are other options for fruit and vegetable preservation. The capital costs of containers and the energy requirements for canning make this option out of reach for family level food preservation in most cases, but canning can still be the basis for successful small industries. Drying may be the lowest cost, most widely relevant strategy, especially for fruit preservation.

Publications on all of these topics are included in this chapter.

Postharvest Food Losses in Developing Countries, MF 07-276, book, 202 pages, National Academy of Sciences, 1978, out of print, but still available from TOOL for Dfl. 18.50.

This valuable, informative book examines the potential of food loss reduction for each of the major food crops, on the small farm or small operator level. Includes cereal grains (e.g. rice, maize, millet, sorghum, wheat), grain legumes

(e.g. beans, peanuts, soybeans), perishables (e.g. cassava, yams, bananas, potatoes) and fish. Losses are identified at each step of harvesting, processing and storage, and low-cost technology options for reducing these losses are discussed.

For the world as a whole, attention to food losses affecting small farmers holds the greatest potential for benefiting the largest numbers of people. The authors note that improvements must take into account social and cultural factors. Increased losses are often associated with the new high yielding varieties, as they overwhelm traditional processing and storage systems.

Education, training and extension are only briefly discussed. Some important issues are raised, such as the need for improved communication between policymakers and village leadership to insure the development of programs in harmony with village needs.

Highly recommended for the general reader involved in rural development work. Very helpful in understanding the factors affecting food losses, and the opportunities for low-cost technology solutions. The technical vocabulary is not difficult, but the language used may still present problems to the non-native English speaker.

Handling and Storage of Food Grains in Tropical and Subtropical Areas, FAO Plant Protection Production Series No. 19, MF 07-269, book, 350 pages, by D.W. Hall, United Nations Food and Agriculture Organization (FAO), 1970, latest edition 1980, \$27.00 from FAO or \$40.00 from UNIPUB.

This is the best technical reference book on grain storage, providing a good summary of the relevant scientific work up to 1970. It will be valuable for anyone working on grain drying and grain storage problems. The text is in readable (not too technical) English.

"This manual describes the causes of grain loss, deterioration and contamination, methods of drying and storage, the design of small and large storage facilities, and also methods of fungus, insect and rodent control." For all of these topics, the author notes traditional local practices which should be more widely encouraged, in addition to relatively simple improved practices.

"Current knowledge of modern handling and storage techniques is derived from industrial countries, which are mainly in the temperate regions of the world. This knowledge has only limited application under the climatic conditions of tropical countries."

"Indigenous farmers always have their own methods for assessing the amount of moisture in grain. Some of these provide a fairly reliable estimate of the grain's suitability for safe storage. These methods include pressing the grain with the thumb nail; crushing the grains between the fingers; biting the grain; rattling a number of grains in a tin; obtaining the 'feel' of the grain by smelling a handful and shaking it; or by plunging the hand (fingers extended) into ... a sack or heap. With long experience a man can judge whether the grain or kernel is suitable for storage ... However ... inconsistency can arise due to differences of opinion when the person concerned feels ill."

"The mixture of wood ash or sand with food grains is carried out in many areas This method appears to rely for its effectiveness upon the fact that the materials used fill the intergranular spaces and thereby restrict insect movement Mineral dusts ... scratch the thin waterproofing layer of wax which exists on the outside surface of the insect cuticle, allowing loss of water which leads to death."

“Condensation problems, especially in metal silos, occur in the tropics particularly in areas where the sky is clear during both day and night Metal silos should be light in color to reflect most of the incoming radiation during the day. The major temperature changes normally required to cause condensation can be avoided by providing adequate shade to prevent large gains of energy in the grain.”

The author does support the use of some insecticides which are now known to be more dangerous and undesirable than previously supposed in 1970.

Highly recommended.

Appropriate Technology for Grain Storage, MF 07-262, book, 94 pages, by the Community Development Trust Fund of Tanzania, out of print.

This report documents a very important example of a successful strategy to stimulate villagers to create their own appropriate technologies for grain storage. The wealth of knowledge held by the Tanzanian villagers about their own specific local problems in grain storage emerged from dialogues with a team of outsiders (Tanzanians and foreigners). Potentially relevant experience from external sources was made known to the villagers, who criticized, modified and added to this store of possibilities. The villagers then designed three sets of improvements that matched different needs within the village. The outsiders thus served as resource people and facilitators, yet left the choice of actions to the very people who would best know what constraints they faced and what they could realistically afford to do. The entire process stimulated an awareness among the villagers of the high level of their own collective knowledge and capability of solving their own problems.

"The team aimed not to impose an alien analysis of the problem on the villagers but to work from the basis of their perceived and understood reality The villagers already had 'parts' of solutions to their storage problems. It was the aim of this project to reinforce these existing solutions so that they would be more effective, not to replace them with new solutions."

"Villagers found it hard to understand that the team had not brought a solution to the storage problem, that it did not want simply to convince or force them to do something, and it did not have some gift for them It was only after having carried a certain line of design (the Nigerian crib) forward in discussions for several weeks only to drop it when the villagers brought up serious criticisms, that the team's credibility was finally established. It was then clear that the team did not have a vested interest in any particular design."

Village discussion groups told the visiting team that home drying of grain was an essential element of any improved storage system. The grain could not be dried in the fields because the farmers could not prevent the destruction of the crops by wild pigs. Preventing the pigs from entering the fields would require a level of cooperation that the villagers said they realistically did not yet have. "Such an example highlights three important reasons why the dialogue approach places such a problem area as grain storage in the context of the total village reality. 1) The significance of some seemingly technical detail of a development problem can easily be misunderstood. For instance, a well meaning expert might have argued that farmers should not harvest their maize while moist; they should let it dry in the fields, and then store it in such and such a way. Such an unfortunately common 'outside' approach would be bound to fail because it lays down rules for the farmers and takes no account of the reality of wild pigs. 2) The dialogue approach generates awareness of interrelated development problems that can be taken up in turn. For instance, the planning committee of the project village has already discussed block

farming in relation to the problem of protection against pigs ... 3) By pursuing problems back to their origins, discussion groups confront what are sometimes called 'limit situations', that is, points where they quite genuinely say, 'Tumeshindwa!' ('We have failed!'). By defining and objectifying limit situations and then by focusing human energy on them, they are ultimately overcome. It is the experience of bursting through a previously limiting situation that constitutes the liberating effect of adult education."

An excellent example of technical assistance in the context of real community participation. Highly recommended.

Small Farm Grain Storage, MF 07-278, set of three volumes, "Preparing Grain for Storage," "Enemies of Stored Grain," and "Storage Techniques and Models," 500 pages total, by Carl Lindblad and Laurel Druben, 1976, single volumes \$12.50 each (overseas orders add \$3.00 for surface mail, \$5.00 for airmail); Spanish version, **Almacenamiento del Grano** (one volume, all-inclusive, 331 pages), available for \$19.95 (overseas orders add \$3.00 for surface mail, \$5.00 for airmail); from VITA; English editions also available from TOOL.

This three-volume set of books was prepared to be used by local development workers, based on materials developed by the Peace Corps and other organizations. It is simpler but not as comprehensive as (and much more expensive than) **PostHarvest Food Losses in Developing Countries** (1978) by the National Academy of Sciences, and **Handling and Storage of Food Grains in Tropical and Subtropical Areas** (1975) by the U.N. Food and Agriculture Organization (FAO).

"Using a format of plain language and informative illustrations, the handbook gives some background to the world's grain storage problem; presents construction plans for grain dryer and storage facilities; offers information on insect and rodent control (with and without the use of poisons); provides shortened, illustrated versions of text material to serve as guidelines for extension agents who wish to prepare their own materials.

"A main aim of the manual is to present its material in a form as close as possible to the way in which the extension agent needs the information in order to pass it on successfully. Ideally, the only adaptations an extension agent should have to make using the material are to translate it (not in all cases) and/or to add culturally specific illustrations or photos. Or the manual material can be used as a base for audio-visual presentations. The idea is for the manual to serve as an idea facilitator and communication link between the development worker and his audience."

The authors explain the storage problem; the characteristics of grain and how these affect grain storage considerations; grain, moisture and air and the interaction between these; and important notes on the preparation of grain for storage.

There is a major section on grain dryers (95 pages) which includes complete production and operating instructions for 3 different solar dryers, pit & above ground oil barrel dryers, and improved traditional units such as the maize (corn) drying and storage crib (made of bamboo). Instructions for sun-drying using plastic sheets, and descriptions of the University of the Philippines and International Rice Research Institute (IRRI) rice dryers are provided.

Storage methods are covered in 150 pages, including use of the following: baskets, cloth or burlap sacks, airtight structures, underground pits, plastic sacks, metal drums and bins, earthen structures, cement and concrete structures, and ferrocement pits and bins.

Manual on Improved Farm and Village-Level Grain Storage Methods MF 07-274, book, 243 pages, by David Dichter and Associates, 1978, DM16 (US \$9.00) plus postage from GTZ.

This handbook provides a good explanation of the important considerations that are keys to better grain storage. The introduction also describes the grain storage problem quite well. Photos and text for the construction of 4 different small storage containers are provided. The descriptions, however, are too wordy and not always well matched with the drawings. Standard designs for sun dryers are also shown, but no cost or output figures are given. As a resource for equipment, this handbook is not as complete as we'd like to see.

The text, which could be shortened considerably, takes the form of lectures with questions and answers. It is intended to be used as a training manual for extension workers in a standard extension effort (in which grain storage designs are chosen by a central agency for dissemination). The book does emphasize the importance of understanding the principles of good grain storage and basing improvements on traditional techniques, rather than the transfer of an alien grain storage technology.

Storage of Food Grain: A Guide for Extension Workers, MF 07-281, book, 33 pages, by Abdel-Hamid F. Abdel-Aziz, FAO, 1975, out of print.

Based on an FAO farm and community grain storage project and the Save Grain Campaign in India, this short book is intended to help extension personnel in planning and implementing extension programs for improved grain storage at the farm level. (Some 70% of India's grain is consumed at the farm level, never entering urban markets.) There is little technical information presented; rather, the material covered is the organization rather than the content of an extension effort.

The author takes a conventional information transfer extension approach, but he is sensitive to the value of traditional techniques. He urges creation of a range of storage options for farmers of different income levels, including full use of traditional systems with any necessary improvements. The author stresses practical skills training over scientific explanations; he may even be underestimating the importance of understanding principles. A variety of helpful communication aids and strategies are presented.

Guide to the Manufacture of Metal Bins, plans, 17 pages, and **Domestic Grain Storage Bins**, MF 07-285, booklet, 25 pages, Save Grain Campaign, India, out of print.

Complete technical drawings for making four sizes of sheet metal grain storage bins. The booklet gives step by step instructions to be used with the plans. Capacity of the bins ranges from 0.4 cubic meters (230 kgs of paddy or 300 kgs of wheat) to 1.35 cubic meters (750 kgs of paddy or 1000 kgs of wheat). The lightweight bins are easily transported when empty, and can be lifted by one person. These bins were developed by the Indian Grain Storage Institute as part of the nationwide Save Grain Campaign.

China: Grain Storage Structures, MF 07-295, book, 127 pages, FAO, 1982, \$18.00 from UNIPUB.

This is a review of storage structures visited by an FAO study group in 1979. The primary type is a unique clay/straw silo based on a traditional Chinese building technique, in which bundles of straw soaked in wet clay are worked together to form solid, well-insulated walls. Originally built in small sizes (e.g. 4m diameter, 2m high, 25 cubic meter capacity), these were later built in much larger sizes (260 cubic meter average capacity). 70,000 large units were built during the 20 years prior to 1979.

The advantages of these silos are claimed to be:

- "—low cost per ton stored grain (usually half the cost of warehouses);
- locally available material (no steel, cement, etc.);
- no specialized labour required (regular labour of a grain depot can build);
- earthquake resistance (claimed, to some extent);
- lot sizes convenient (50-250 tons/silo normally);
- protection of stored grain is good."

Details of this construction technique are described, along with photos and drawings.

Evaluation of the Bissa: An Indigenous Storage Bin, MF 07-266, paper, 38 pages, by K.B. Palipane, 1978, available on request from the Rice Processing R&D Centre, Paddy Marketing Board, Jayanthi Mawatha, Anuradhapura, Sri Lanka.

This paper describes and evaluates the traditional Bissa rice storage bin used by farmers in Sri Lanka. Results of a careful test of the structure are presented. Drawings for construction are included. The bin is made of woven sticks plastered with clay, with a thatched roof

In Sri Lanka, only 40% of the total rice production is marketed; consequently, there is a high level of on-farm storage for seeds and family consumption. "In improving farm level storage, it is always better to improve and popularize the already existing permanent storage structures, which can be fabricated from material easily available at farm level at a low cost and also whose design and operation is known."

The Bissa is a permanent structure with a capacity from 1/2 ton to 10 tons. A 5-ton Bissa is estimated to require 164 person-hours for construction, plus the use of local materials, for a total cost in Sri Lanka of \$50. The total maintenance, depreciation, and loading/unloading costs for 1 year are about \$1.75 per ton. Properly dried paddy (rice) is generally stored for 6 months without any significant loss of quality or quantity.

"The majority of the farmers do not adopt any pest controlling practices because according to them, the damage due to insect attack is negligible if clean dry paddy is stored in the structure A main defect of this structure is that it has no facilities for aeration to bring down temperature rises." Some minor changes are proposed.

"According to the farmers, a properly maintained Bissa will last for over fifty years."

A good example of a successful, low-cost traditional grain storage bin that could be relevant in many other countries.

Storage Management, MF 07-293, book, approximately 100 pages, by Malcolm Harper, 1982, International Labor Office, out of print.

These materials are intended for use in training managers of agricultural cooperatives, with 35-40 hours (6-7 days) of instruction. Participants are expected to gain an understanding of how to evaluate costs, benefits and risks of storage estimate the amount of space needed; choose between storage methods; keep good records; measure grain moisture content and temperature; and control pests. Includes a good collection of common problems and typical tasks for students to perform.

Storing Vegetables and Fruits in Basements, Cellars, Outbuildings and Pits, Home and Garden Bulletin No. 119, MF 07-294, 17 pages, U.S. Dept. of Agriculture, revised September 1973, out of print.

An introduction to storage cellars and pits, for use in vegetable and fruit storage in areas where the winter temperatures average 30 degrees Fahrenheit or less (SAC).

Principles of Potato Storage, MF 07-290, book, 105 pages, by Robert Booth and Roy Shaw, International Potato Center, \$5.45 plus postage from Winrock International, Agribookstore, 1611 North Kent Street, Arlington, Virginia 22209, USA; also available from SKAT.

A thorough reference book on storage from the main international center devoted to the study of the potato; this is the place to look first on this topic The principles are explained, and the technologies embodying these principles range from very simple and low cost to complicated and more expensive. Management and economics are also discussed.

Fruit and Vegetable Processing, Food Cycle Technology Source Book No. 2, MF 07-297, booklet, 67 pages, UNIFEM, 1988, from UNIFEM, 304 East 45th Street, Room FF-614, New York, New York 10017, USA.

A review of many options for fruit and vegetable preservation, along with illustrations of some small-scale equipment. Products include preserves, pickles, drinks, wines, vinegars, and salted and dried foods. Seven case studies of projects are presented.

Home-Scale Processing and Preservation of Fruits and Vegetables, MF 07-270, booklet, 68 pages, Central Food Technological Research Institute, 1977 (7th edition), Rs. 10.00 from Director, Central Food Technological Research Institute, Mysore 570 013, India.

This Indian publication is a very useful one, both for the material it contains and for the model it presents to other countries. A basic introduction of home-scale food processing technologies (canning, drying, and pickling) is combined with specific fruit and vegetable recipes, a detailed glossary in several important Indian languages, and access information for equipment and supplies.

The wide array of preserved food options is designed to be tasty, reduce produce losses, and improve nutritional levels. Products include cashew apple

extract, mango leather, jackfruit nectar, guava cheese, papaya pickles, and bamboo chutney. Processing time adjustments for higher altitudes are included in the detailed processing charts. The authors also describe a low-cost, complete community canning unit.

"An effort has been made to present information in a simple and comprehensive manner, so that an average housewife can use it without any difficulty. It can be used by home science and catering institutions as well as agricultural extension agencies."

Stocking Up: How to Preserve the Foods You Grow Naturally, MF 07-292 book, 532 pages, edited by Carol Huppung, 1977, \$24.95 from Rodale.

Rodale Press's bestseller, written for U.S. readers, nevertheless has some information relevant to developing countries. Drying of fruits and the production of fruit leathers, underground storage of fruits and vegetables (in cold areas), pickling, making jams and jellies, making fruit and vegetable juices, the production of cheese and yogurt, and the smoking of meat and fish are covered. The varieties of fruits and vegetables are only those common to the U.S. Although limited by the absence of much of the equipment used in the examples, alert readers in developing countries will find some hints and nuggets of information not found in the other books on these subjects.

Putting Food By, book, 565 pages, by Ruth Hertzberg, Beatrice Vaughn, and Janet Greene, 1975, \$9.95 from WEA.

Here is a basic food preservation manual for the U.S. reader, with information on canning, freezing, drying and curing of fruits, vegetables, meats and fish. Although freezing equipment and canning supplies (especially lids and jars) are relatively more expensive in developing countries (and thus impractical in most places), some of the other techniques are widely relevant. Root cellars, for example, are of interest in mountainous regions such as Nepal and the Andes. Some but not all of the fruits and vegetables covered are found in developing countries. The final section includes recipes for making soap, sausages, cottage cheese and many meals that use the foods preserved with the methods in the book.

Preservation of Foods, MF 07-289, book, 86 pages, by Agromisa, 1984, Dfl. 7.50 from TOOL.

A review of techniques for long term food preservation, including canning with glass jars or tins, drying, salting, pickling, jam and juice making, and smoking (meat and fish). The varieties of fruits and vegetables covered are those common to Western countries.

Food Drying, publication IDRC-195e, MF 07-287, book, 104 pages, edited by Gordon Yaciuk, 1981, IDRC, out of print.

These conference papers examine a variety of traditional and improved technologies for drying rice, potatoes, vegetables, fish and coffee.

The Indonesian paper comes to the interesting conclusion that additional investment in concrete floors for sun drying of rice is superior to investment in artificial dryers. Authors from Thailand and the Philippines, in contrast, support

some specific artificial dryer designs that they believe to be advantageous.

Dry It, You'll Like It, MF 07-264, book, 74 pages, by G. MacManiman, \$4.95 from WEA.

This book covers drying for food preservation. Dried food is nutritionally better than canned food. No preservatives, chemicals or electricity (freezer) are required. Dried food takes up 1/6 or less of the usual storage space required, and can usually be stored a couple of years.

This is a simple little book with general instructions for all food drying. Specific information is given for most American fruits, vegetables, and some herbs. Two pages on meat and fish are included, along with recipes.

Plans for a food dehydrator using simple tools and made largely of wood are complete and easy to follow. It does require some source of low heat that remains constant near 100 degrees Fahrenheit—the dehydrator could possibly be suspended over a wood-burning stove while other cooking is taking place.

How to Dry Fruits and Vegetables, MF 07-272, leaflet, 12 pages, 1976, Action for Food Production (AFPRO), Technical Information Service, New Delhi, India, out of print.

The purpose of this booklet is to give practical information to people in the rural areas of India "on how to dry fruits and vegetables, which can then be preserved from times of plenty to be used in the lean seasons of the year. It can also be used as a handbook to teach village level Community Development workers."

The information is comprehensive, with tables on preparation hints, treatment before dehydration, dehydrated product yields, description of dried condition, and specific fruit and vegetable refreshing data. Heavy emphasis is given to treatment of various fruits with sulphur, which prevents discoloration during the drying process and provides some protection against insects in storage. (We, however, do not feel that it is yet clear whether the widespread use of sulphur is justified, due to the added expense and potential health side effects of this preservative—editors.)

Drying and Processing Tree Fruits, MF 07-286, booklet, 20 pages, by D. McGeorge McBean, CSIRO, Australia, 1976, out of print.

This describes the important considerations in the sundrying of apricots, peaches, nectarines, pears and prunes during hot dry weather on open wooden trays, as is done in Australia. The use of sulphur is expected and described.

"Halved fruits are placed close together and one layer thick on self-stacking wooden trays They should be made of relatively knot-free softwood which has been smooth sawn or dressed so as to prevent particles of wood from becoming embedded in the soft fruit tissue. The use of hardwood results in staining of the fruit.. The drying-yard should be established where fruit is exposed to direct sunlight for as long as possible during the day and where prevailing winds blow directly across the trays. It should not be near roads or pathways used by wheeled vehicles as this will result in dusty and dirty dried fruit Trays of fruit are generally placed directly on the ground but it has been shown that fruit dries a little faster if it is suspended up to one metre above ground level ... probably due to convective wind currents carrying moisture away from the drying surface of the

fruit. Elevation of trays results in cleaner dried fruit and also appreciably reduces backbreaking labour during spreading and picking up If heavy dews are likely (particularly if associated with poor drying conditions during the day) trays should be stacked at night."

It is recommended that only properly ripe fruit of the same size be dried together, so that a full tray will be dry at the same time. Bruised, damaged, and over-ripe fruit, if included, will reduce the quality of the product, increase the chance of insect infestation, and be likely to stick to the wooden trays.

Sun Dry Your Fruits and Vegetables, MF 07-282, booklet, 26 pages, U.S. Dept. Of Agriculture, 1958, out of print in 1985.

This illustrated step-by-step guide was written for extension workers in simple English. Other than simple household equipment, the only items required are wooden trays, and for some fruits, a large box to cover the trays while sulphur is burned inside. The booklet emphasizes the need for cleanliness and hot, dry air that circulates freely. A chart gives directions for many different fruits and vegetables. Steaming is recommended prior to drying for most vegetables. A step-by-step description of the use of sulphur when drying some fruits is provided, as are notes on the preparation of dried food for use.

A Survey of Solar Agricultural Dryers, Technical Report T99, MF 07-283, book, 144 pages, 1975, \$9.00 from BRACE; also from TOOL.

This book focuses on experiments with the use of small-scale agricultural dryers in rural areas of developing nations. Includes a representative sample of different types of dryers; emphasizes local improvements and adaptation. There are 24 case studies of different dryers in a variety of countries; each one has photos, full construction drawings, and the address of the people involved.

The dryers included are used for: coffee, grapes, fruits, vegetables, cereals, grains, herbs, flowers, and lumber. They are divided into natural and sun dryers, direct solar dryers, mixed mode solar dryers, and indirect solar dryers.

Highly recommended.

Potential of Solar Agricultural Dryers in Developing Areas, paper, 8 pages, by T.A. Lawand, 1977, included in *Technology for Solar Energy Utilization*, MF 23-563, UNIDO, 1978 (see review).

This paper, presented to a UNIDO conference in 1977, summarizes the principles of solar dryers, as well as surveying various types of dryers from around the world. Some of the examples: a grape drying rack from Australia a cabinet dryer from Syria, a glass-roof greenhouse dryer from Brazil, a wind-ventilated dryer from Syria, and a lumber seasoning kiln from India. There is also a bibliography.

This is a condensation of the information contained in the more complete **Survey of Solar Agricultural Dryers** from Brace Research Institute (see review). Lawand hopes to stimulate people to adapt these designs and develop their own to fit local conditions.

A good introduction to the subject.

How to Make a Solar Cabinet Dryer for Agricultural Produce, MF 07273, booklet (#L-6), 11 pages of text, diagrams and charts, 1965 (revised 1973), \$1.75 from BRACE.

"The dryer is essentially a solar hot box, in which fruit, vegetables or other matter can be dehydrated." It dries produce cheaply for storage, without insect or dust contamination, and reduces moisture content to the lowest necessary level. The dryer is a rectangular container, insulated at the base and sides, with a transparent roof and circular air flow. The framework can be made of virtually any material— woven bamboo, metal, plywood, adobe, or brick. Insulation can consist of "locally available materials such as wood shavings, sawdust, bagasse, coconut fiber, reject wool, or animal hair."

The capacity of the dryer is 7.5 kg per square meter of drying area. Brace's prototype units have dried 3 kgs of onions or okra in 2 days. A model in Syria cost \$14.00; one in Barbados cost \$23.00 to build. Brace estimates the annual operating cost at \$6.89. The temperatures inside reach 70-80 degrees Centigrade, so the dryer can also be used for warming foods and other materials.

A production drawing for this dryer can also be obtained from Brace (see below).

Production Drawing for a Solar Cabinet Dryer, MF 07-273, 1972, 1 large sheet \$2.50 from BRACE.

This is drawing #T-85 from Brace, designed for use with the booklet listed above.

Solar Drying: Practical Methods of Food Preservation, MF 07-296, book, 127 pages, International Labour Office, 1986, 20 Swiss Francs from ILO.

This manual on solar drying is primarily of interest for its coverage of techniques of preparing food for drying. The drying of fish, vegetables, fruits and grains are all covered. Also presented is information on the theory and practice of drying, with coverage of both traditional sun drying and solar drying using covered dryers. These solar dryers are not well presented, nor do they represent the best selection of proven models. We recommend that readers interested in building dryers themselves consult **A Survey of Solar Agricultural Dryers** (see review), which has a far better selection.

How to Build a Solar Crop Dryer, MF 07-271, plans, 9 pages, New Mexico Solar Energy Association, out of print.

Detailed plans for building a crop dryer. Air is drawn in at the bottom, heated by a collector, and then sent up through the drying chamber. An adjustable vent allows control of temperature (which may reach 120 degrees Fahrenheit). The unit is 4 feet wide and has 36 square feet of drying area, enough for almost 2 bushels of food.

Although the cost is estimated at \$60.00, the design can be varied to use cheaper local materials. It is suitable for drying small amounts of fruits and vegetables. Very simple.

Cookbook for Building a Solar Crop Dryer, MF 07-284, booklet, 18 pages, by Arnold and Maria Valdez, 1977, out of print.

A short set of plans with instructions for making a solar fruit and vegetable dryer out of wood, glass, corrugated metal and metal lathe. The design is similar to that in **How to Build a Solar Crop Dryer**.

Construction of a Brick Hot Air Copra Dryer, Technical Bulletin No. 9, MF 07-263, booklet, by S. Mason, 1972, Papua New Guinea, limited supply available, K3.50 from DWS.

"The purpose of this bulletin is to assist the indigenous copra owner who has had no experience in construction work, to construct his own drier, so that a better quality copra can be produced more economically"

"The drier consists of a brick building with a minimum of timber exposed in areas subject to the heated air flow from the firebox. Fuel such as wood or coconut shells is fed into the firebox at the front of the drier. The heat from the fire warms a mild steel radiating plate on the hot air chamber which in turn heats the air within the drier."

This dryer was designed to have an output of six 155-pound bags of copra per week. Construction details, materials list, glossary of technical terms, drawings of the dryer, and drawings of a wooden mold for making individual bricks are all provided. This manual does not tell you how to make the bricks. **"Selection of Materials for Stabilized Brick Manufacture** Technical Bulletin #5 should be studied to assist in selecting materials suitable to make bricks" (see review).

One limitation of this leaflet is that the assembly drawings are hard to read. However, this appears to be a sound design, one that the author claims prevents accidental fires.

Solar Grain Drying: Progress and Potential, MF 07-280, booklet, 14 pages, by G. Foster and R. Peart, 1976, Office of Communication, U .S. Department of Agriculture, out of print.

This booklet describes studies of solar grain dryers, particularly for rice and corn, from the midwestern United States. The dryers are made of inflated polyethylene (soft plastic) shells to heat air as in a greenhouse; the air was then pumped through the grain.

These tests were primarily to determine the feasibility of solar grain drying. Details of the designs are not given. The booklet does offer general descriptions of grain drying systems.

The Performance and Economic Feasibility of Solar Grain Drying Systems, Agricultural Economic Report No. 396, MF 07-275, booklet, 33 pages, by Walter G. Heid, Commodity Economics Division, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, February 1978, paper copy \$17.00 (code A03) from NTIS.

This is a summary of the performance of various types of solar grain drying systems from the midwestern U.S. All are for large-scale, temperate climate agriculture. Some of these dryers use electric air blowers and/or auxiliary electric heating. There is a short explanation of the various parts of a crop drying system. Tables compare size, capacity, performance from tests, and costs of 8 different

systems now in use.

The emphasis in this paper is on economic evaluation (rapidly becoming more favorable to solar drying since this report was published), rather than on the principles of operation.

Drying Equipment for Cereal Grains and Other Agricultural Produce, MF 07-265, plans, 11 pages, by Keith Markwardt, CARE, Manila, Philippines, out of print.

The agricultural dryer described in these plans was built by a Peace Corps volunteer in the Philippines. It consists of three components: 1) a concrete and brick furnace 48" by 24" which uses rice hulls for fuel; 2) an 8' by 16' drying bed; and 3) a gasoline, diesel, or electric powered fan which blows heated air from the furnace through the perforated floor of the drying bed. The dryer has been used for fish, copra, and a variety of grains and vegetables. Drying capacity varies with type of produce. One batch (50 cavan, or 2500 kg) of paddy dries in approximately 6-8 hours at an operating cost (including engine fuel, maintenance, and depreciation) of about \$3.00.

The advantage of this design is the use of rice hulls (plentiful in many rural areas) to cheaply fuel the furnace. The builders estimate that this dryer can be constructed for about \$500 in the Philippines. Such a dryer might best be used by a cooperative, allowing farmers to collectively meet this initial investment and take advantage of the high capacity and low operating costs.

Simple Grain Drier, MF 07-277, 2 descriptive articles plus complete dimensional drawings and photos, 15 pages total, by W. Chancellor, U.C. Davis, out of print in 1985.

This information includes clear production drawings and a report from field tests in Asia.

"Local availability of drying facilities not only can reduce spoilage losses in storage but can also promote increased production through strengthening the practicality of double cropping in irrigated areas where the offseason crop is harvested in humid weather."

This dryer has the following elements: "a horizontal metal surface placed over a fire pit; use of animal power to stir the shallow layer of grain placed on the metal surface; grain temperature, and thus the rate of moisture evaporation, controlled by adjusting the rate of fuel use."

The dryer is made mostly of sheet metal, and is of simple design. It is easy to build and requires no special skills to operate. It can be disassembled for easy transport and storage. The stirring blade is attached to the smoke stack base with a wooden bearing. A durable thermometer is needed, but the operator can estimate temperatures from the smell and feel of the grain. Cost of all materials was approximately \$160.

This unit is for use in humid or rainy conditions when sun drying would not be effective. "In tests using rice straw as the fuel, it was determined that the straw contained in the grain bundles brought to the threshing site would provide enough fuel to complete the drying operation." Grain dried by this process did not germinate, however, so this should not be used for seed.

More than one animal is needed, to allow the animals to rest alternately. Two persons are required. The 16-foot diameter design is capable of drying 1000 lbs. Of rice at a time, reducing moisture from 24% to 14% in 4 hours. 160 lbs. of moderately

dry straw was used as the fuel.

Small-Scale Processing of Fish, MF 07-291, book, 118 pages, by the International Labour Office, 1982, \$12.25 from ILO- also available from TOOL, ITDG, and VITA.

People involved in technical support to small fisheries may find this a useful reference. It covers a spectrum of techniques and technologies that range from virtually no-cost procedures to substantial investment in equipment. Salting, drying, fermenting, smoking, boiling and canning are discussed, along with general guidelines to reduce spoilage before, during and after processing. A variety of simple smoking kilns is shown. An attempt is made to assess the costs of the various processing techniques and technologies.

How to Salt Fish, MF 07-288, pamphlet, 9 pages, by D. Casper, VITA, reprinted in **Village Technology Handbook**.

"The process of salting fish is influenced by weather, size and species of fish and the quality of the salt used. Therefore, experience is needed to adapt the process outlined here to your situation Salted fish, if properly packed to protect it from excessive moisture, will not spoil."

This article covers the complete process—preparing the fish, salting, washing and drying to remove excess salt, and air drying. It is a simple process requiring only knives, waterproof vats, and large amounts of salt. Curing in the brine takes 12-15 days in warm weather, up to 21 in cold weather. Six days of warm weather are required for drying.

Rural Home Techniques, Volume 1: Food Preservation, FAO Economic and Social Development Series #51, MF 07-267, leaflets, total of 60 pages, 1976, Home Economics and Social Programmes Service, FAO, out of print; may be available in the future from UNIPUB.

This is the first of a planned series of Food and Agriculture Organization (FAO) publications on equipment and techniques related to food preparation, handling, and storage. Drawings illustrating the steps in the preservation of fish and meat are presented, with text in English, Spanish, and French. Includes cleaning, filleting splitting, dry salting, wet salting, smoke drying, sun drying, and storage of fish, and salting, salt-drying, rendering fat, and storage of meat. Drawings of all the tools needed include 10 different simple designs for smoking ovens made of commonly available materials.

Fish Processing, Food Cycle Technology Source Book No. 4, MF 07-298, booklet 91 pages, UNIFEM, 1988, from UNIFEM, 304 East 45th Street, Room FF614 New York, New York 10017, USA.

This is a review of simple methods of fish processing, with illustrations of dryers and smokers. Three case studies of projects are briefly discussed.

ADDITIONAL REFERENCES ON CROP STORAGE

Village Technology in Eastern Africa reviews some of the simple food preservation and storage technologies affordable at the village level; see BACKGROUND READING.

Rural Women: Their Integration in Development Programs and How Simple Intermediate Technologies Can Help Them suggests the use of enclosed solar dryers, black plastic sheets for direct drying, and improved grain storage units; see BACKGROUND READING.

Low Cost Rural Equipment Suitable for Manufacture in East Africa includes designs for a solar dryer and a grain storage crib; see AGRICULTURAL TOOLS.

Rice: Post Harvest Technology describes the technical requirements for rice drying and storage; see AGRICULTURAL TOOLS.

Plans for Low-Cost Farming Implements includes drawings of platform carts with drying pans for crop drying in areas of frequent rains, crops can be brought in under a protective roof quickly; see AGRICULTURAL TOOLS.